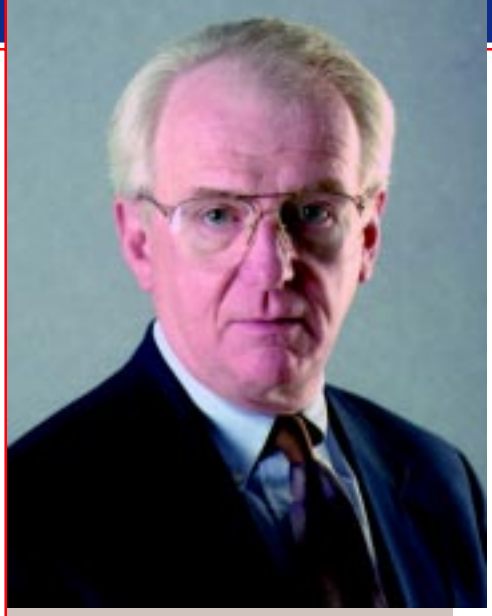

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Energy Solutions for the 21st Century

Picture a mountain 2,000 feet high and 10 miles long. Beside the mountain is a lake 10 miles long, 9 miles wide, and 60 feet deep. Above the mountain is a giant balloon 10 miles in diameter. Every year the world uses that mountain of coal, that lake of oil, and that balloon of natural gas.

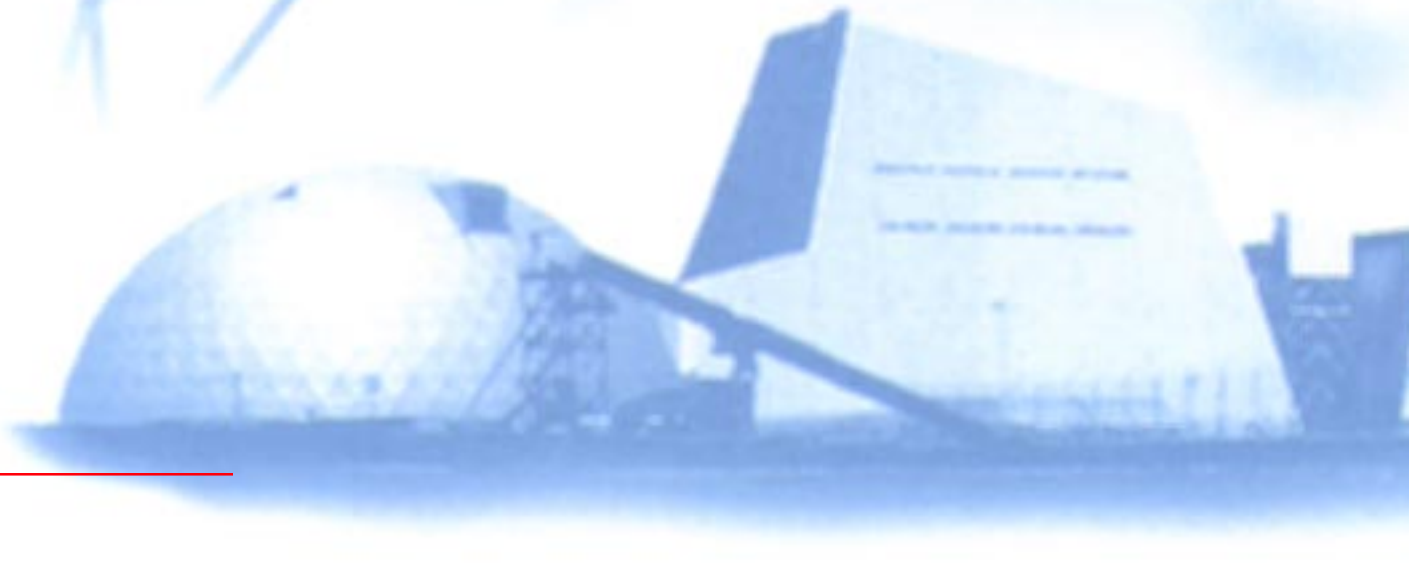
We in the U.S. use almost one quarter of that whole amount. In just over 20 years, the balloon will be 13 miles in diameter, the lake 16 miles long, and the mountain 2,700 feet high.

Will we be able to find enough gas to fill the balloon? Can we use these fuels without harming our environment? Can we extract them from the earth without environmental degradation? The answers to these questions constitute the fossil-energy mission of the Federal Energy Technology Center (FETC).

Energy is the fuel that drives our economy and allows us to enjoy our excellent standard of living. Eighty-five percent of that energy comes from fossil fuels. Supplies of fossil fuels are limited, but until cost-effective, sustainable energy sources are developed and deployed, we will have to depend on fossil fuels to sustain our way of life. While rapid advances are being made in development of sustainable energy sources, it may well take a century or more before they are deployed widely enough to largely supplant fossil fuels. FETC is developing solutions to fossil-energy supply and use issues that will ensure adequate supplies and clean use of fossil fuels in the 21st century.

Energy Supply Challenges

The U.S. has used about half of its economically recoverable supply of conventional natural gas. The demand for this clean-burning, easy-to-use fuel is projected to grow rapidly. Transportation costs for gas imports from countries other than Canada and Mexico, which have pipelines in place, are extremely expensive. FETC efforts to increase our natural gas supply include technologies to recover more of our conventional supplies, and to develop non-conventional supplies from tight sands, coal beds, and natural gas hydrate deposits.



FETC is also developing technologies that require less fuel to provide the required energy. U.S. power plants operate with an average efficiency of about 33 percent. FETC is developing technologies for power generation from gas, coal, and blends of fossil and renewable fuels that can be installed on existing or new power plants to raise efficiencies and reduce emissions. In the mid timeframe, new technologies will be available with efficiencies greater than 50 percent; longer-term solutions will provide efficiencies exceeding 70 percent. Deployed in a 21st century plant, these technologies could eventually result in needing only half the fuel that is used in a currently operating plant. FETC is also developing advanced fuels for use in more efficient engines, which will result in doubled automobile fuel efficiency without reduced space or comfort.

Environmental Challenges

Americans desire a clean environment and have expectations that the environment will continue to become cleaner. FETC is developing technologies to reduce emissions of pollutants from power generation facilities to vanishing levels and at modest costs. In addition, there is considerable scientific concern about potential global climate change that may be attributable to increased utilization of fossil fuels. The U.S. is a signatory of the recent Kyoto treaty concerning these matters. (See page 13.) Quantitative scientific answers on the magnitude of potential climate changes and their effects on people and ecosystems will require additional research. Nevertheless, FETC activities to develop high-efficiency power systems and recover coalbed methane would reduce the potential magnitude of climate changes. FETC is also conducting long-range research on sequestration of carbon dioxide—in case sequestration is eventually required to ameliorate climate-change effects.

Vision 21 and CO_2 Sequestration

DOE's drive to improve energy efficiency and address local and regional needs for heat, steam, fuels, chemicals, or carbon products has centered FETC's research and development (R&D) on the Vision 21 effort. For the next century, FETC envisions an integrated complex of sophisticated technologies that combines power generation, manufacturing, and the option of CO_2 sequestration into a highly efficient *Vision 21 EnergyPlex*. An EnergyPlex is a modular, adaptable, high efficiency, nonpolluting energy facility that can be integrated into a specific market, community, or region.

There is no single magic bullet to provide the clean energy required for economic prosperity in the 21st century. Clearly, a multifaceted approach is needed and FETC is responding to the challenge by offering energy solutions. Some of these energy solutions are discussed in greater detail in this issue of *FETC Focus*.

1. ***Vision 21:*** This "crown jewel" of FETC's programs integrates energy and environmental technologies. Vision 21 combines advanced energy and pollution-control technologies into customizable packages that offer higher net efficiency than stand-alone technologies.

2. ***Develop more efficient electric power generation with lower emissions:*** FETC is developing systems that burn less coal and gas to obtain energy, while reducing emissions.

3. ***Increase natural gas supplies:*** FETC develops economically and environmentally sound technologies for natural gas detection, extraction, conversion, distribution, and storage.

4. ***Engage the international community's interest:*** FETC is actively promoting the use of improved technologies internationally.

5. ***Promote energy conservation:*** FETC's Energy Management Services are available to help government facilities meet mandatory energy-reduction targets.

A fleet of Vision 21 EnergyPlexes will be capable of providing low-cost energy from coal (at better than 60-percent efficiency) or natural gas (at better than 75-percent efficiency) while coproducing fuels and chemicals and achieving reduced CO_2 emissions. Vision 21 is a culmination of existing R&D on fossil-fuel power generation that will take advantage of the full potential of our abundant fossil-fuel resources.

The Vision 21 EnergyPlex attacks the energy problem from all sides at once: energy supply, power-generation efficiency, and options for CO_2 sequestration. The EnergyPlex integrates many technology components, including coal gasifiers, hot gas cleanup systems, fluidized-bed combustion, fuel cells, advanced turbines, high-temperature heat exchangers, oxygen and hydrogen separators, and conversion processes. The goal is a "green" facility whose only significant environmental impact is its physical footprint on the ground, and even the size of the footprint is being reduced.

Sequestration refers to the capture and storage of CO_2 emissions to prevent them from entering the atmosphere. This long-range technology is being developed in parallel with Vision 21 in case the U.S. decides to sharply curtail its CO_2 emissions in the future. Sequestration could also be applied to existing facilities. Storage possibilities include natural sinks, such as the ocean, and various underground reservoirs, such as unminable coal beds, deep saline (salt water) aquifers, and depleted oil and gas reservoirs. Sequestration in these environments is expected to be effective for centuries.

CO_2 Sequestration

CO_2 Enhanced Natural Sinks

- Ocean (Dissolves CO_2)
- Green Plants (Forest, Cover Crops, Algae, Phytoplankton)

CO_2 Capture

CO_2 Direct Sequestration

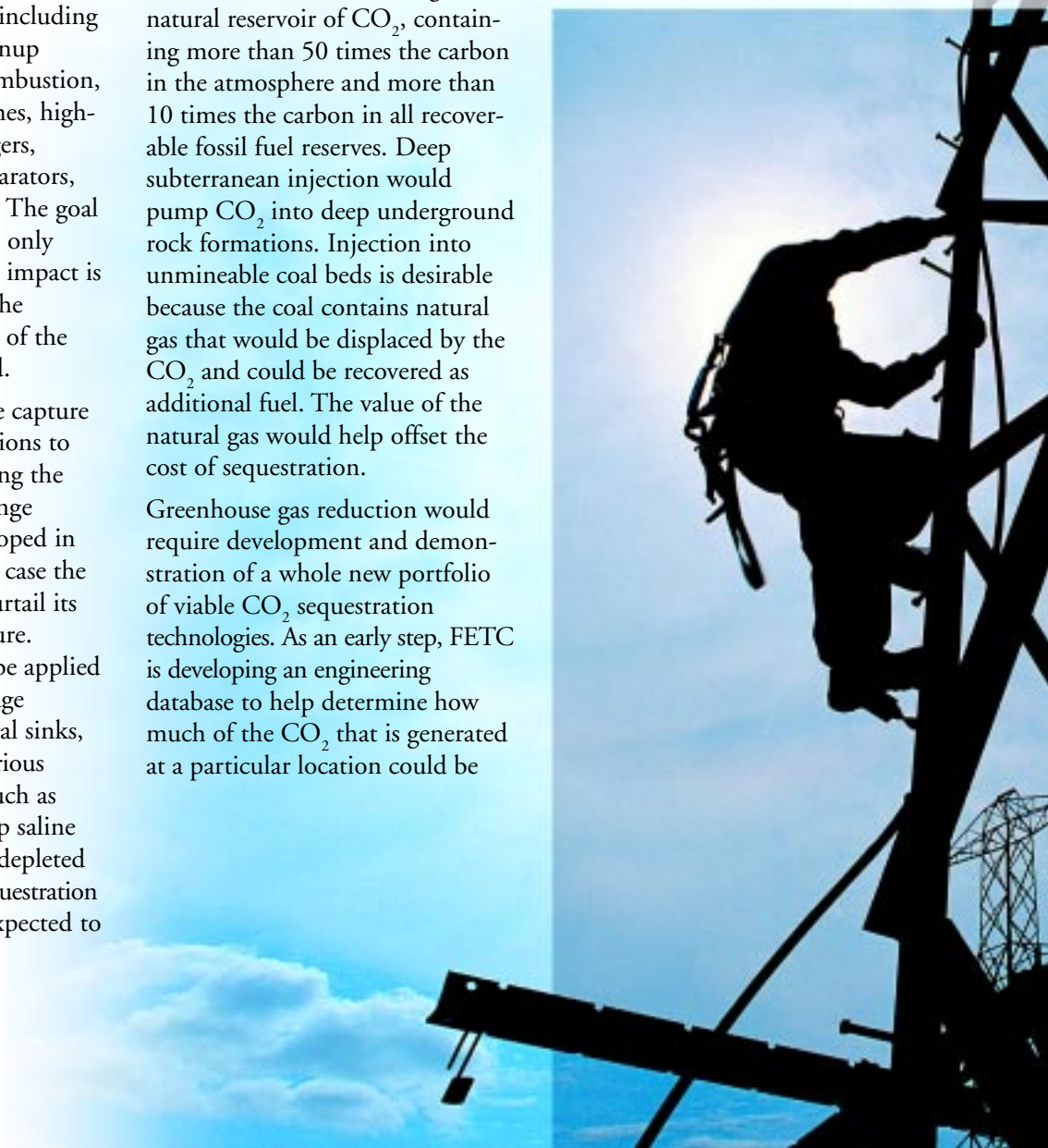
Geologic Storage

- Unminable Coal Beds
- Old Oil & Gas Fields
- Aquifers

Research on actual processes that sequester CO_2 is just beginning. Initial research is focused on deep sea and underground injection and injection into unmineable coal beds. Deep sea injection is inviting because the ocean is the largest natural reservoir of CO_2, containing more than 50 times the carbon in the atmosphere and more than 10 times the carbon in all recoverable fossil fuel reserves. Deep subterranean injection would pump CO_2 into deep underground rock formations. Injection into unmineable coal beds is desirable because the coal contains natural gas that would be displaced by the CO_2 and could be recovered as additional fuel. The value of the natural gas would help offset the cost of sequestration.

Greenhouse gas reduction would require development and demonstration of a whole new portfolio of viable CO_2 sequestration technologies. As an early step, FETC is developing an engineering database to help determine how much of the CO_2 that is generated at a particular location could be sequestered, where it could be sequestered, at what distance, and at what cost.

CO_2 sequestration is intimately related to other fossil energy research. It is an integral part of Vision 21.



More Efficient Electric-Power Generation

The energy sector is responsible for close to 80 percent of humankind's CO_2 emissions. Nearly 60 percent of all electricity generated worldwide comes from power plants that burn fossil fuels, either coal or natural gas. The current fleet-average efficiency for all fossil-based electricity generators in the U.S. is only about 33 percent. Improving efficiency will pay benefits in all respects, including lower costs, lower emissions of pollutants, less need to use limited fossil resources, and reduction of CO_2 emissions because less fuel is burned.

FETC already has developed and demonstrated advanced turbine systems. The promising strategy of cofiring biomass with coal uses technologies that have been demonstrated by FETC. Both utilize our natural resources more effectively and also reduce net CO_2 emissions.

Advanced Natural Gas Turbine Systems—Much of the near-term growth in power generation will be through installation of gas turbines. Today's gas-turbine efficiency is around 30 percent, but in a combined cycle system, it can exceed 50 percent. FETC is developing technologies to boost combined cycle efficiency to 60 percent or greater, thereby reducing CO_2 emissions by nearly 20 percent. DOE-supported advanced-turbine-system technology is already being incorporated in current manufacturing.

Biomass cofiring—Burning of biomass (wood, sawdust, etc.) is environmentally friendly, because it can effectively utilize waste products such as bagasse, tree bark, and waste wood, thus preventing the pollution relating to disposal of these products and avoiding the environmental impacts of fossil-fuel extraction. The CO_2 originally consumed from the atmosphere by plants during photosynthesis is returned to the atmosphere later when the plants are burned. Since burning of biomass adds no extra

CO_2 to the atmosphere, displacing some coal with biomass during cofiring reduces the net addition of CO_2 to the atmosphere, compared to firing coal alone. Cofiring results in more efficient utilization of the biomass than biomass-only power facilities and helps facilitate the eventual transition to a sustainable energy supply. Cofiring is already in use or under test at several utilities, and FETC is working to enhance the near-term potential of cofiring.

Natural Gas Supply

Natural gas is useful in high-efficiency combined-cycle power generation that integrates combustion turbines and steam. At the current price for natural gas (which is expected to remain stable), gas provides the least-cost option for new electric power plants wherever natural gas is available. Natural gas contains almost no sulfur and nitrogen oxide emissions from its combustion are low, resulting in little environmental degradation from natural-gas power plants. In addition, the resulting CO_2 emissions from natural-gas power generation is about half that from coal, making gas an extremely attractive fuel.

To meet the growing demand, FETC is implementing a DOE program to increase reserves and production of gas. The program has two components: one near term, one visionary. Near-term, the goal is to enable an increase in domestic gas consumption by 27 percent, from 22 trillion cubic feet (Tcf) in 1995 to 28 Tcf by 2010. Strategies to achieve this are (1) developing conventional natural gas reserves more efficiently, (2) improving gas extraction from "tight" geologic formations, and (3) recovering methane from coal beds.

The visionary part of the program has FETC scientists investigating what is perhaps our planet's greatest natural gas resource: methane hydrates, which are ice-like solids made of natural gas (methane) and water. They occur beneath the Arctic permafrost and beneath the ocean floor. The size of the resource is imprecisely known, but vast areas of hydrates have been identified in the Gulf of Mexico, Alaska, Canada, Russia, and off the coasts of several states.

FETC has led government research in methane hydrates since interest first developed in 1982, and with the renewed interest in this resource, FETC once again is studying ways to produce commercial gas from this unconventional resource.

International Cooperation and Conservation

Two other strategies are extremely important in reducing the environmental impacts of greater usage of fossil fuels on a worldwide basis: (1) getting other nations of the world on the same page with us in deploying superior technologies, and (2) attacking the demand-side of the energy equation by promoting energy conservation.

International Cooperation—Simply put, international cooperation involves persuading people to adopt our advanced technologies, so they won't undergo the same long, inefficient, pollution-generating development that we have. Reducing CO_2 emissions and

other pollutants are important goals of this cooperation, but there are also huge economic stakes. The energy market is now global, and how effectively we interact internationally will affect our own prosperity. We must maximize the effectiveness of federal R&D dollars through promotion and deployment of clean, efficient energy systems worldwide and through cooperative research and technology development with other nations.

Energy Conservation—Equally important is the demand side of the energy equation. Our other strategies for limiting pollution from utilization of fossil energy and making efficient use of our limited natural resources involve the supply side. The trick, of course, is improved efficiency—more efficient lighting, heating, cooling, transportation, communication, computing equipment, etc.—consuming less energy while enabling economic expansion.

The Energy Policy Act of 1992 mandates reduced energy consumption in all U.S. government buildings (over 3 billion square feet of floor space), and the Federal Energy Management Program administers the national effort. FETC's Energy Management Services Group provides scientific consultations on energy efficiency to other government agencies.

The outcome of FETC's aggressive technology development and deployment will leave future generations of Americans a more livable nation that enjoys a thriving energy sector and a variety of safe energy alternatives. Many of the technology programs just discussed are presented in the following articles in this issue of *FETC Focus*.

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"Prudence clearly dictates that new technologies be developed to provide additional options to meet evolving environmental, economic, and security needs."

Comprehensive National Energy Strategy, April 1998, page 9.

"Ultimately, the continued development of new technologies that provide diverse energy resources, improve the efficiency of end-use, and reduce the negative environmental effects of energy production and use is key to maintaining our high quality of life. . . the Government ensures the flow of new and cleaner energy technologies by funding energy research, development, and demonstration."

Comprehensive National Energy Strategy, April 1998, page 2.

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